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Introduction

The purpose of this research is to advance understanding of how to improve the care and outcomes for persons with Traumatic Brain Injury (TBI), numbering over 200,000 in the past decade in US forces. The project vision is to improve TBI functional classification, health care processes, and rehabilitation outcomes by establishing and activating a self-sustaining system with a new level of integration of health science informatics-based web tools and human organization, empowered by partnership with patients (and their family caregivers) and their preferences [1-4]. The goal is to provide a platform and process for innovative solutions that can overcome barriers and meet identified needs in patients with TBI [5]. The first set of objectives is focused on configuration and initial deployment and use of a health science-based web technology platform for representation of the WHO International Classification of Functioning, Disability and Health (ICF) in a computable form, with mapping of the computable ICF to varied user interfaces to create a cross-systems tool set for TBI rehabilitation models and functional health optimization. The second set of objectives is focused on development of organizational knowledge that would guide decisions and actions for the expanded deployment and use of the envisioned computable ICF framework and ICF-Integrator tool set.

Body

With a focus on Traumatic Brain Injury (TBI) and at the same time supporting broader utilities, the Specific Aims and their objectives are designed to enable delivery of an enterprise-scalable and silo-bridging web toolset that advances and enhances the systematic and science-based assessment, disability decision-making, and continuity of rehabilitation services, plus to provide new knowledge about software development processes, potential impact upon DoD and VA workflows, and expected patient benefits and costs.

The overall study Hypothesis is that use of the mdlogix Clinical Research Management System-Health Science Process Framework (“CRMS-HSPF”) can rapidly engage users and enable effective implementation of the WHO ICF to provide Infrastructure and Interfaces that meet the needs of diverse users for standardization in classification coding for TBI soldiers and veterans.

The first set of objectives is focused on configuration of an existing health science-based web technology platform, the mdlogix CRMS-HSPF, for representation of the WHO International Classification of Functioning, Disability and Health (ICF) in a computable form, with mapping of the computable ICF to varied user interfaces to create a cross-systems tool set for TBI rehabilitation models and functional health optimization.

The second set of objectives is focused on development of organizational knowledge that would guide decisions and actions for the expanded deployment and use of the envisioned computable ICF framework and ICF-Integrator tool set. To understand barriers to the cross-systems and multi-level engagement of patients, providers, health scientists, and administrators with the software interface design process, organizational constraints will be studied in collaboration with DoD and VHA managers.

The objectives and their tasks are organized with five Specific Aims. These are:

Aim 1: Implement ICF infrastructure in a computational logic form

Aim 2: Implement a set of web tools for mapping assessment tools to ICF and supporting associated data collection, display, and management.

Aim 3: Incorporate the ICF Code Set for TBI

Aim 4: Study organizational constraints in collaboration with DoD and VHA managers

Aim 5: Address the Hypothesis using multiple methods

The summary Objectives and Research Accomplishments for each of the Specific Aims follow.

Aim 1: Implement ICF infrastructure in a computational logic form

Objectives: The primary question to be answered in Aim 1 is: Can the challenges of computerizing ICF be sufficiently overcome by novel use of computational logic? To date, the conceptual value of ICF has been constrained by its complexity and a lack of software tools that combine representational computability with usability and flexibility, for example due to the need for representation of heterogeneous logical relationships, such as in person-environment interactions [6], and at the same time, a lack of logical

consistency in ICF [7].

Research Accomplishments: In the 90 day period prior to the start of the project, and subsequently, the ICF and its potential utility for application to advancing the care of patients with TBI were discussed in multiple meetings with VHA leaders and personnel, starting with the Polytrauma Rehabilitation Center in San Antonio, Texas, followed by the Polytrauma Continuum of Care group in Richmond, Virginia, and in Tampa, Florida. From these detailed discussions, it is apparent that use of ICF is not considered to be of high clinical care priority. Further, in these settings, it appears that there is little if any direct experience with use of ICF.

In parallel, a series of discussions were held with Dr. Mark Musen, and his team at the Stanford Center of Biomedical Informatics Research. They also were awarded funding under the Clinical Functional Assessment W81XWH-11-JPC1HIT-CFA program, with a focus on development of their ICF mapping approach with application to musculoskeletal injuries. Dr. Musen's team in prior work with the World Health Organization (WHO) created a basic ontology representation of the full ICF, which is stored and publically available at National Center for Biomedical Ontology (NCBO): <http://bioportal.bioontology.org/ontologies/ICF/?p=summary>. Dr. Musen's team expressed strong interest in collaboration with the mdlogix team, offering both teams and the CFA program potential for complementarity and perhaps synergies.

A result of our analysis of the discussions in the above meetings and what we have learned from the activities in the other Aims (discussed below), is that the availability of ICF in computable ontology form from NCBO is sufficient to address the ICF computational infrastructure needs for the other Aims, within the project scope. A corollary is that efforts in the first year have focused more on these other Aims, described below, including deployment of the CRMS-HSPF platform. Nevertheless, as we move forward in the second year with implementation, we will continue to study and document the potential need for greater formalized ICF expressivity and logical consistency.

In addition, numerous enhancements were made to the CRMS-HSPF infrastructure. One area of continued work is to improve the performance speed with complex data collection assessment tools, which is important with data collection tools mapped to ICF, for usability.

Aim 2: Implement a set of web tools for mapping assessment tools to ICF and supporting associated data collection, display, and management.

Objectives: The primary question to be answered in Aim 2 is: Can the needs of diverse TBI stakeholders be satisfied with a set of web tools that are integrated using ICF as the organizing and functional framework? The envisioned and planned result will be a cross-systems web toolset for TBI acute care and rehabilitation services that is integrated with an underlying logical framework and an explicit computerized coding system. It will enable, as integral to clinical care, comparative effectiveness research (CER) and other scientific models for generating new knowledge and supporting innovation. Data management, query, display, and export capabilities will be enhanced by using the logic of ICF to link to clinical data and to define populations.

Research Accomplishments: Achievements in the first year under this Aim include:

- selection of a set of standard assessment rehabilitation instruments
- completion of mapping specification from these rehabilitation instruments to ICF
- further analysis of mapping model
- creation of a core set of User Stories for software implementation
- deployment of CRMS-HSPF with two active TBI studies in Richmond
- implementation of study protocols and data collection forms for those studies
- bug fixes and numerous enhancements to CRMS-HSPF
- implementation of patient and family caregiver self-report interfaces
- expansion of CRMS-HSPF interactive data query and visualization capabilities.

These accomplishments are described following.

Selection of a set of standard assessment rehabilitation instruments

A comprehensive ‘Assessment Set’ of rehabilitation assessment tools (data collection instruments) used in Occupational, Physical, and Speech and Language Therapy has been selected to cover much of the ICF TBI Core Set, with input from the St. Louis VA. These are:

Physical Therapy (PT) Assessment Tools

- Functional Independence Measure (FIM)
- Berg Balance Scale (BBS)
- Activities-specific Balance Confidence scale (ABC)
- Dizziness Handicap Inventory (DHI)
- Tinetti Assessment Tool (also known as POMA – the Performance-Oriented Mobility Assessment)
- Functional Gait Assessment (FGA)
- The Timed Up and Go (TUG) test
- High Level Mobility Assessment tool (HiMAT)
- Lower Extremity Functional Scale
- Oswestry Low Back Pain Disability Questionnaire
- Neurological Exam (10 different tests: Visual screening, 2-point discrimination, Light touch, Vibration, Proprioception/Kinesthesia, Pain, Deep tendon reflexes (DTR), Cranial nerves I-XII screen, Coordination testing (dysdiadokokinesia, finger-to-nose, rapid finger or foot movements, heel to shin to ankle, etc), and the Romberg balance test.)
- Dix-Hallpike test for vestibular dysfunction
- Roll test for vestibular dysfunction
- Range of motion (ROM) for lower extremities
- Manual muscle testing (MMT) for lower extremities
- Balance tests using the NeuroCom System including the rhythmic weight shift to left & right, rhythmic weight shift to front & back, limits of stability
- Disabilities of the Arm, Shoulder and Hand (DASH) test

Occupational Therapy (OT) Assessments

- Grip Strength Testing (Using Jamar Dynamometer)
- Range of Motion Testing (Upper Extremity)
- Manual Muscle Testing (Upper Extremity)
- FIM (Functional Independence Measure)

- Baylor Visual Perceptual Assessment
- Non-standardized safety evaluation measure questionnaire
- Sensation Testing (Light Touch, non-standardized)
- FIM: Functional Independence Measure

Speech-Language Pathology (SLP) Assessments

- Functional Assessment of Verbal Reasoning and Executive Strategies (FAVRES)
- Rivermead Behavioral Memory Test (RBMT)
- Functional Assessment of Communication Skills for Adults (ASHA FACS)

Of note, the above assessments represent only one specific VA center that has a polytrauma unit. **From our investigation, the VA does not have a standard specified assessment protocol across the nation.** Since there are a wide variety of assessment tools for the TBI, other VA centers use different sets of assessments. However, the individual assessment tools in this portion of the study are commonly used in most VA centers. The purpose of choosing a particular VA protocol was to ascertain how a typical facility's assessment addresses the areas on the ICF Core Set for TBI, developed by the World Health Organization. The above Assessment Set serves two purposes: one is for implementation as a usable set, and the second is to be representative of many other potential sets of assessment instruments, in terms of ICF mapping.

Completion of mapping specification from these rehabilitation instruments to ICF

A mapping specification was completed between the above data collection forms and each of their individual items and the ICF TBI Comprehensive Core Set. Provided in the Appendices, this ICF Core Set consists of 2 Body Structure items, 37 Body Functions items, 62 Activities and Participation items, and 40 Environment Factors items. The mapping model specifies the data collection assessment tool and item, the ICF category, the matching level (direct, more specific, more general), the specific ICF code full or partial matches, the severity or extent of the health problem, the source of information (clinician determined, patient determined, proxy determined, other method), and personal factors.

The mapping data were obtained from personnel with three different professional clinical roles, occupational, physical, and speech and language rehabilitation.

The specificity of mapping from the Assessment Set of ICF codes is shown in below, Table 1.

Table 1. Mapping Specificity			
OT Body Function	Number Used	Total Items	Percentage
Direct Match	7	37	18.92%
More Specific than Code	12	37	32.43%
More General than Code	18	37	48.65%
OT Activities & Participation			

	Number Used	Total Items Used	Percentage
Direct Match	8	31	25.81%
More Specific than Code	0	31	0.00%
More General than Code	23	31	74.19%
OT Environmental Factors			
	Number Used	Total Items Used	Percentage
Direct Match	0	0	0.00%
More Specific than Code	0	0	0.00%
More General than Code	0	0	0.00%

PT Body Function			
	Number Used	Total Codes Used	Percentage
Direct Match	5	76	6.58%
More Specific than Code	22	76	28.95%
More General than Code	49	76	64.47%
PT Activities & Participation			
	Number Used	Total Items Used	Percentage
Direct Match	52	154	33.77%
More Specific than Code	50	154	32.47%
More General than Code	52	154	33.77%
PT Environmental Factors			
	Number Used	Total Items Used	Percentage
Direct Match	0	0	0.00%
More Specific than Code	0	0	0.00%
More General than Code	0	0	0.00%

SLP Body Function			
	Number Used	Total Items Used	Percentage
Direct Match	2	51	3.92%
More Specific than Code	33	51	64.71%
More General than Code	16	51	31.37%
SLP Activities & Participation			
	Number Used	Total Items Used	Percentage
Direct Match	10	42	23.81%
More Specific than Code	10	42	23.81%
More General than Code	22	42	52.38%
SLP Environmental Factors			
	Number Used	Total Items Used	Percentage
Direct Match	0	0	0.00%
More Specific than Code	0	0	0.00%
More General than Code	0	0	0.00%

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These results show the challenge of mapping to ICF, which is a main barrier when rehabilitation sites have established use of a wide variety of assessment instruments, overlapping with and similar to our chosen Assessment Set.

These results also show that this approach to mapping is important by virtue of enabling clinical sites to use any assessment instruments and to map them in this 3-level manner to ICF Codes and sets of Codes (Core Sets).

Of note, four ICF Codes were determined to be covered by the Assessment Set, that are not in the ICF TBI Core Set. These are b265 (Touch Function), b2702) Sensitivity to Pressure, d598 (Self-care, other Specified), and b172 (Calculation Functions). These ICF Codes could be added to the ICF TBI Core Set.

The information content of the Assessment Set regarding determination of severity in accordance with ICF is shown in below table, and varies from 42% for OT Activities & Participation to 100% for SLP Activities and Participation.

Table 2. Severity Determination			
OT Body Function			
	Number Used	Total Items	Percentage
Severity Can be Determined	19	37	51.35%
Severity Cannot be Determined	18	37	48.65%
OT Activities & Participation			
	Number Used	Total Items Used	Percentage
Severity Can be Determined	13	31	41.94%
Severity Cannot be Determined	18	31	58.06%
PT Body Function			
	Number Used	Total Codes Used	Percentage
Severity Can be Determined	58	76	76.32%
Severity Cannot be Determined	18	76	23.68%
PT Activities & Participation			
	Number Used	Total Items Used	Percentage
Severity Can be Determined	153	154	99.35%
Severity Cannot be Determined	1	154	0.65%
SLP Body Function			
	Number Used	Total Items Used	Percentage
Severity Can be Determined	47	51	92.16%
Severity Cannot be Determined	4	51	7.84%

SLP Activities & Participation			
	Number Used	Total Items Used	Percentage
Severity Can be Determined	42	42	100.00%
Severity Cannot be Determined	0	42	0.00%

There is convergence in the mapping, in that more than one profession often indicated the same ICF codes; also, many Assessment Set items mapped to one ICF code.

Hence, the results indicate that the mapping system should have a way of storing information about ICF coding from different professional perspectives so that variance as well as agreement in coding is available for analysis and decision support. In the case of many items linking to one ICF code, there is also a question of how to represent the weighted information content, e.g., to what extent is a mean score meaningful?

Another standout of these results is the limited number of Environmental codes addressed by the three rehabilitation professions despite published scientific evidence showing that Environmental Factors are among the most predictive of long term successful community integration. This highlights an important planned ICF-Integrator software feature, which is that based on an ICF Core Set, it will indicate deficiencies in assessment sets and protocols which should be addressed.

Further analysis of mapping model

The mapping model continues to be analyzed for added specification and prioritization of potential extension and refinement. Inputs for this analysis include the above mapping activities and summary results, discussions with the Stanford team and examination of their work, external participation and discussions with Centers for Medicare and Medicaid Services (CMS) and Social Security Administration (SSA) groups, collaboration with other organizations, for example Econometrica, Inc., American Psychiatric Association, Stanford Center for Integrative Medicine, and preparation and submission of major funding applications, including to CMS and to National Institutes of Health (NIH).

The mapping model established and being further developed by the Stanford team is complementary to the mapping model developed herein by the mdlogix team. The Stanford model focuses on linking data collection to automatically generate exact ICF qualifier coding, whereas the mdlogix model focuses on defining a broader relationship between data collection and existing defined sets of codes (i.e., ICF Core Sets). From discussion with the Stanford team, it is apparent that user features and interfaces (e.g., ‘Use Cases’, ‘User Stories”) are a currently limiting factor for gaining the utilities from broader use of ICF.

A key aspect of the mapping model is to document and track progress in functional areas, so that assignment of severity (as in yes/no questions) is essential to track progress. The principles of ICF state that ICF codes without qualifiers have no inherent meaning. The results from the severity coverage mapping point to a problem with assessments, in that without rating of severity, the ability to track progress is hampered. This is another indication of how mapping automation can be used to make apparent and visible to users the gaps and limitations in any specified set of assessments, relevant not just for the St. Louis VA but most likely others as well.

Although study of the mapping model and how it can be enhanced will continue, the results to date validate the original plan and indicate that the current model is sufficient to proceed with for implementation and subsequent evaluation from the user perspective. The planned software will be able to address the above issues, supporting standards with flexibility and variability across different professional areas, and hence with potential to improve cross-disciplinary coordination.

Creation of a core set of User Stories for software implementation

A core set of User Stories has been written. In the user-centered agile development process, User Stories serve as the central specification of software features to be implemented, and are the focus of team communication about the associated technical details, tasks, clarifications, deployment scheduling, and defects and defect correction. Pivotal Tracker is powerful web tool used to manage User Stories and agile development. An example User Story is shown below.

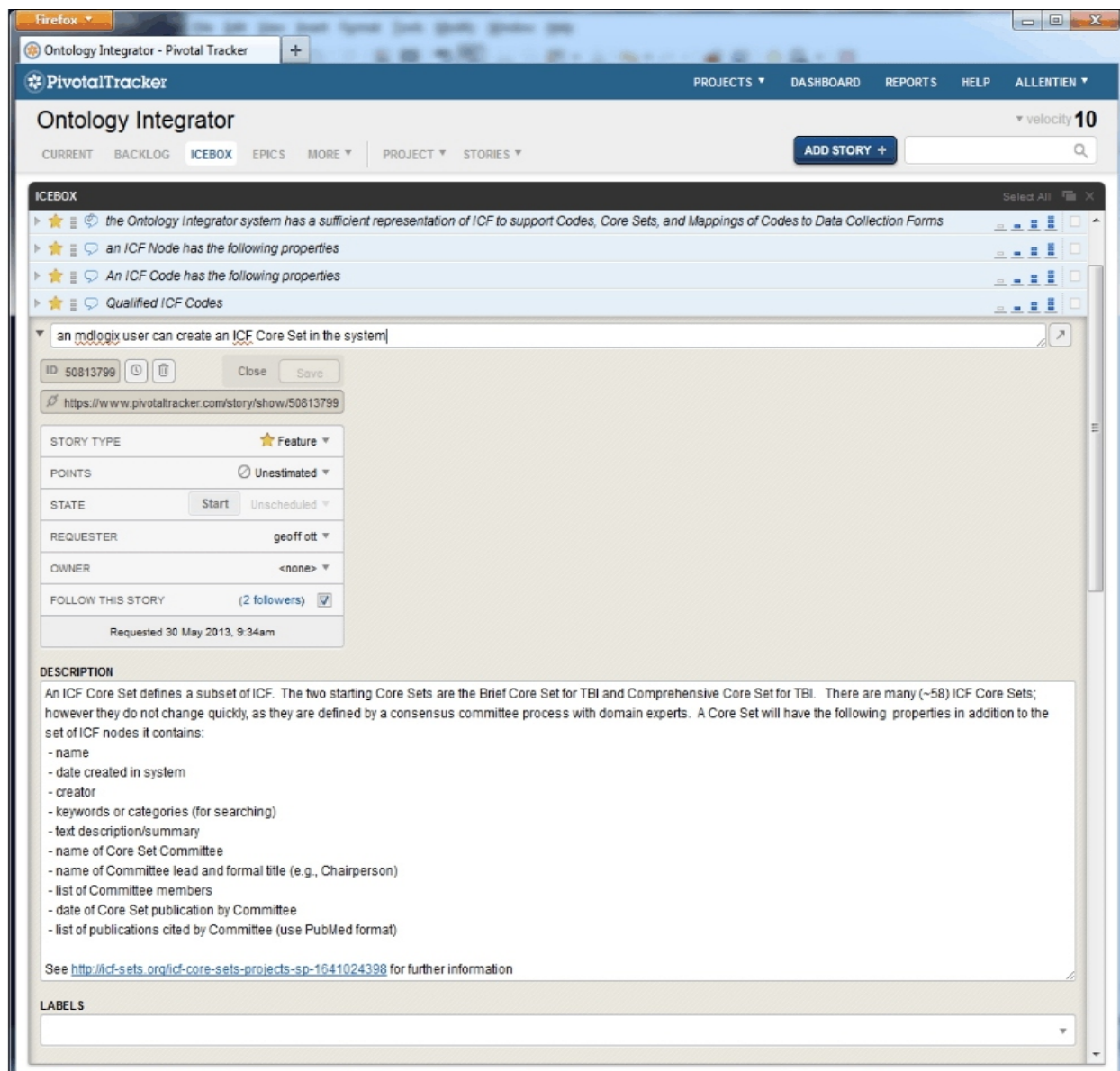


Figure 1. Example User Story: “An mdlogix user can create an ICF Core Set in the system”

Implementation of these User Stories was not started in the first year. This delay was due to prioritized focus on the other activities, including the importance of operational deployment of CRMS-HSPF within the VA environment with active use by TBI clinical research teams.

Implementation will be carried out in the second year, starting with representation of the entire ICF, the TBI Core Sets (Comprehensive and Brief), and mapping with the Assessment Set described above.

Deployment of CRMS-HSPF with two active TBI studies in Richmond

The two active studies using CRMS are:

- Olfactory and taste dysfunction among U.S. military personnel deployed to Iraq and Afghanistan: A feasibility study.
- Defense and Veterans Brain Injury Center (DVBIC): Prospective Traumatic Brain Injury (TBI) Tracking Protocol (20-year multi-center study).

The Olfactory Study is fully operational, while the Prospective Study is still being finalized in both research details and regulatory approvals.

Deployment of CRMS within the VA environment and obtaining regulatory approval is a key accomplishment. The process and needed steps to accomplish this are:

1. Implementation of a dedicated VA CRMS instance in our datacenter.
2. Multiple demonstrations of CRMS to investigators and their teams at multiple sites.
3. Loading of study protocols into VA CRMS.
4. Identification of study checklists and data collection forms for implementation.
5. Migration of VA CRMS to state-of-the-art hardware platform provided by Hewlett Packard.
6. Configuration of system modules for VA-specific use.
7. Development of a Data Use Agreement with Hunter Holmes McGuire Veterans Affairs.
8. Development of a Data Use Agreement with Defense Veterans Brain Injury Center (DVBIC).
9. Presentation to the Polytrauma Rehabilitation Center Research Committee.
10. Training of study teams.
11. Implementation of study data collection forms.
12. Ongoing intermittent changes to study data collections based on study team inputs.

Use of CRMS in these two studies is expected to facilitate the other objectives and tasks, and to inform the overall study hypothesis.

Implementation of study protocols and data collection forms for those studies

The two TBI studies were implemented using multiple CRMS modules, including Registry, Protocol Schema, and Forms modules. Study schedules were built using the Protocol Schema module. Subject eligibility enrollment criteria and consent management were built using the Registry module. The largest amount of effort is for implementation of the data collection forms using the Forms module. As the investigators and their teams evolved study specifications and form details, these

changes were rapidly implemented (and continue to be modified with the Prospective Study).

Example screens follow to illustrate Study Scheduling and Study Consent Management.



CTF schedule v2		Time Periods						
		Baseline	Year 1 Visit	Year 2 Visit	Year 5 Visit	Year 10 Visit	Year 15 Visit	Year 20 Visit
		Baseline within + 2 weeks	d366; within +/- 30 days	Year 3; within +/- 60 days	Year 6; within +/- 180 days	Year 11; within +/- 180 days	Year 16; within +/- 180 days	Year 21; within +/- 180 days
Forms	collapse all							
▼ Original Forms								
PCL-C	 R	R	R	R	R	R	R	R
NSI	 R	R	R	R	R	R	R	R
CTF - Tracking Form	R	R						
▼ Updated Forms								
SWLS	 R	R	R	R	R	R	R	R
Audit-C	 R	R	R	R	R	R	R	R
GOSE	R	R	R	R	R	R	R	R
CTF - Follow-up Form	R		R	R	R	R	R	R
MPAI-4	 R	R	R	R	R	R	R	R
Headache Module	R	R	R	R	R	R	R	R
Contact Information Form	R	R						

Figure 2. Study Schedule Schema



TEST TBI TEST study for the Olfactory and Taste project Status: Active PI: Ott, Geoffrey IRB Number: Lead Study Coordinator: Department: Lead Research Nurse:									
Study Consents <i>* You must enter a Consent IRB Approval Date before making a Consent active.</i>  Has embedded agreement(s) ● Active ● In Development ● Archived									
Consent Status All									
Type	Name	Version Number	Version Date	IRB Approval Date	Activation Date				
● Main	mTBI group consent			*		Edit	New Version	Delete	Make Active
● Main	mTBI group consent	1	04/01/2013	04/01/2013	04/12/2013	View	New Version	Delete	Make Active
Type	Name	Version Number	Version Date	IRB Approval Date	Activation Date				
● Donor Consent	Control group consent	1	04/01/2013	04/01/2013	04/12/2013	View	New Version	Delete	Make Active
Type	Name	Version Number	Version Date	IRB Approval Date	Activation Date				
● Main	Control group main consent	1	04/01/2013	04/01/2013	04/19/2013	View	New Version	Delete	Make Active
Type	Name	Version Number	Version Date	IRB Approval Date	Activation Date				
● Main	Main Consent 	1	03/18/2013	04/11/2013	09/20/2013	View	New Version	Delete	Make Active
Type	Name	Version Number	Version Date	IRB Approval Date	Activation Date				
● Other	HIPAA Form	06/04/2012	06/04/2012	06/04/2012	10/16/2013	View	New Version	Delete	Make Active
● Other	HIPAA Form	08/27/2013	08/27/2013	08/27/2013	09/20/2013	View	New Version	Delete	Make Active
● Other	HIPAA Form	1	06/04/2012	06/04/2012	10/16/2013	View	New Version	Delete	Make Active
● Other	HIPAA Form	05/03/2010	05/03/2010	05/03/2010	10/16/2013	View	New Version	Delete	Make Active

Figure 3. Study Consent Management

Data collection forms built (for both studies) include:

- Barratt Impulsiveness Scale - Short

- BPAQ-SF
- BSI-18 (total score)
- Clinical data collected from medical records
- CPRS Problem list
- Demographics and Health Questionnaire
- Exit Interview
- Neurobehavioral Symptom Inventory
- Neurobehavioral Symptom Inventory (Modified)
- OSU TBI Identification Method - Short Form
- PCL-C
- Primary and Secondary Mental Health and Psychosocial Problems
- TBI Screening - tracking
- Trail Making Test Form A
- Trail Making Test Form B
- Audit-C
- CTF - Contact Information Form
- CTF - Family Member Follow-up Form
- CTF - Follow-up Form
- CTF - Tracking Form
- CTF - Tracking Form v2.15.2012
- CTF Optional Headache Module
- Glasgow Outcome Scale Extended
- Mayo-Portland Adaptability Inventory-4
- Rancho Los Amigos Cognitive Scale - Inpatient
- Rancho Los Amigos Cognitive Scale - Outpatient
- Satisfaction with Life Scale

Some examples of implementation of these forms follow.

Form: Glasgow Outcome Scale Extended

Subject Number: CTF-01
Completed on: March 04, 2014

Please check the answers to your questions.
If you are comfortable with the responses, then please click the **finalize** button at the bottom of the screen.

[Show complete audit log](#)
[printer friendly version](#)

#	QUESTION	RESPONSE	EDIT
1	Interviewer	Jane Assesor	Change
2	Respondent:	Subject alone	Change
4	(2.) Is the assistance of another person at home essential every day for some activities of daily living?	No	Change
7	(3.) Are you able to shop without assistance?	No	Change
8	(3a.) Were you able to shop without assistance before the injury?	Yes	Change
(9.) [For this next question, before you answer, I will read you a list of choices from which you should choose at least one.]			
22	What do you feel is the most important factor in your outcome (problems reported here) from the blast exposure?	<ul style="list-style-type: none"> Effects of emotional stress 	Change

[Exit >](#)
[Finalize >](#)

Version: 1.1.1

Figure 5. Data entry verification at form completion.

Another form is shown below in the section on patient self-report.

Bug fixes and numerous enhancements to CRMS-HSPF

In the course of deployment of CRMS and the implementation of the two study protocols and their sets of data collection forms, as well as with improvements to patient and family caregiver self-report interfaces, numerous enhancements were made. As well, various minor software defects were uncovered and corrected. A major improvement was made to speed up the display and performance of complex data collection forms. Changes were made at the database server level to meet DoD and VA security requirements, including automatic encryption.

Implementation of patient and family caregiver self-report interfaces

New interfaces were implemented for a 'Patient and Family Portal', providing user-friendly screens and functions for patients and family caregivers to enter self-report

data. The interfaces are designed for use on desktop, laptop, and tablet computers, and are architected to readily be extended for use with smaller mobile devices.

The interfaces are integrated with CRMS, so that once data collection forms are created in CRMS, these forms can be displayed to patients and family caregivers when they

Barratt Impulsiveness Scale - Short Form: Page 2 of possible 3 total:

1: I plan tasks carefully.

2: I do things without thinking.

3: I don't "pay attention."

4: I concentrate easily.

5: I save regularly.

6: I "squirm" at plays or lectures.

7: I am a careful thinker.

8: I plan for job security.

For each item, there is a dropdown menu and two buttons: "Explain my answer..." and "I can't answer because..."

Figure 6. Patient self-report

login. The selection of which forms are displayed is based on study protocol schedules as created in CRMS, e.g., baseline, repeated daily, weekly, monthly, follow-up time periods, and any other defined protocol workflows. The selection of who sees what forms is based on assignment of individuals to studies, supported within CRMS.

These interfaces and the underlying infrastructure will enable the flexible use of any self-report forms to define types of impairments and relevant experienced or observed details for describing functional impairments. The form authoring and mapping will allow use of detailed data collection to categorize different types of disabilities, and to aggregate these using ICF codes and concepts. The protocol scheduling will enable different forms to be presented at different stages in clinical course and calendar time.

Because of the centralized form and item libraries in CRMS, and the capability of automatically pre-filling any forms and their items with any existing data in the system, combined with the capability making role assignments for entering data into specific forms at specific stages of care protocols as well as calendar dates, redundancies that were observed in clinical care and research data collection with multiple staff, could be largely eliminated.

Expansion of CRMS-HSPF interactive data query and visualization capabilities

In parallel with this project, a partnership has been established with Hewlett-Packard Corporation with an OEM agreement for use of an advanced search and interactive data query web system. This system, named Autonomy, is based on IDOL (Intelligent Data Operating Layer (IDOL), which allows for search and processing of structured and unstructured data and text. Autonomy already incorporates SNOMED as a framework for concept-based search of medical records. In the second project year, Autonomy will be integrated with CRMS-HSPF; furthermore, ICF is planned to be added to Autonomy to provide ICF concept-based search and query capabilities.

Aim 3: Incorporate the ICF Code Set for TBI

Objectives: The primary question to be answered in Aim 3 is: Can the existing ICF Core Set for TBI be successfully incorporated as part of ICF-Integrator? Related questions will address more specific infrastructure operational and user interface design aspects. The most tangible result of Aim 3 will be a comprehensive set of items and a software interface for clinical assessment of persons with TBI, linked to the ICF framework, and suitable for research applications.

Research Accomplishments: This Aim has been postponed for completion in the second year. This implementation will be guided by results of the mapping activities and results discussed above.

Aim 4: Study organizational constraints in collaboration with DoD and VHA managers

Objectives: The primary question to be answered in Aim 4 is: What are the organizational constraints to the production deployment of ICF-Integrator within or after this study? Also, what are the barriers, within this study, to the cross-systems and multi-level engagement of patients and families, providers, health scientists, and administrators with the software interface design process.

Research Accomplishments: A collaboration was established with the Relational Coordination Research Consortium (RCRC) led by Professor Jody Gittel at Brandeis University and with Relational Coordination Analytics, Inc. (RCA), a newly established company. Multiple meetings and detailed discussions were held with leadership and staff in the Polytrauma Continuum of Care system in Richmond.

From these inputs and further analysis, the mdlogix team developed an expanded model and process for studying organizational constraints and guiding potential interventions, named 'Relational Network Optimization (RNO)'. The RNO process has three main

phases – Organizational Network Mapping (ONM), Relational Coordination (RC), and Rapid Cycle Improvement (RCI). In addition, modifications were made to the mdlogix suite of Social Network Analysis (SNA) products, adding automated algorithms for calculating parameters of group 'Cohesion' score and individual 'Centrality', 'Key Player', and 'Bridging' scores.

ONM and RC data was collected and initial analysis carried out. The RNO model, the data collection process, and the results are described in the report in the Appendices (“Case Report: Using Relational Network Optimization for Improving Health Care Coordination and Delivery in a Polytrauma Continuum of Care”). These results contain a large amount of information; this information continues to be examined, considered, and analyzed, and it sets a ‘baseline’ for identifying and measuring potential benefits to be gained from implementation of the ICF Integrator.

The activities of Aim 4 took longer than anticipated due to constraints in available personnel time. Based on the difficulty in scheduling meeting with VA staff and engaging them with data specification and collection, the priority of involvement of additional VA sites has been lowered because substantial engagement with other sites would take too long (although we continue to liaise with other sites).

Aim 5: Address the Hypothesis using multiple methods

Objectives: The primary question to be answered in Aim 5 is: What are the benefits to care of persons with TBI from the use of the mdlogix HSPF platform and process to implement the proposed ICF-Integrator web tool set?

Research Accomplishments: This Aim largely remains to be addressed. As the ICF web tools are implemented in the second year, quantitative data on utility and usability will be collected, along with ongoing collection of qualitative data.

Of note, it appears unlikely that it will be practical to obtain IRB approval for engaging patients or family members as direct subjects in this research. Hence evaluation of Aim 5 will in part depend upon simulated data and staff inputs on the software without engagement of patients and their family caregivers.

However, the deployment of CRMS and its use with two TBI studies provides a platform for evaluation in the context of TBI studies that have their separate IRB approvals. The enhancements to the CRMS Patient Portal module will enable it to be used within these (or other) TBI studies. This is a key accomplishment that is expected to facilitate understanding of the potential value of ICF, and in combination with patient reported outcomes, at least within the clinical research context, and providing a stronger basis for understanding potential value in clinical care.

Key Research Accomplishments

- Operational engagement with TBI clinical researchers and the leadership and staff of the Polytrauma Continuum of Care in the Richmond, Virginia VAMC, and at other Polytrauma sites, is a key one major and critical accomplishment, substantially enabling other aspects of this study to proceed.

- We have completed our baseline ‘Relational Network Optimization’ (RNO) process at Richmond VA, including Organizational Network Mapping and Relational Coordination. A draft case report paper is attached.
- As part of the baseline RNO process, automated algorithms for calculating parameters of group 'Cohesion' score and individual 'Centrality', 'Key Player', and 'Bridging' scores were added to the project software tools.
- Data collection and analysis of the specification of the ICF TBI Core Set mapping framework to clinical data collection has been carried out, with completion of the ICF Linking Tables for OT, PT and SLP. Detailed specification of software 'User Stories' that will comprise the ICF-Integrator has been initiated.
- CRMS, the health science process framework (HSPF) for the ICF-Integrator, has been established with all needed data security and other approvals and is in active use with two TBI clinical studies at the Richmond VAMC.
- An updated CRMS 'patient portal' module has been put in place, designed for patient and family care-giver self-report.
- Strategic discussions continue regarding CMS, SSA, and other Federal entities and how use of ICF aligns with ongoing policy and program developments, and clinical needs of patients, and variance amongst rehabilitation providers.

Reportable Outcomes

Results from this research include:

- Manuscript: “Case Report: Using Relational Network Optimization for Improving Health Care Coordination and Delivery in a Polytrauma Continuum of Care”
- Funding applied for: To Centers for Medicare and Medicaid Services (CMS), a Research, Measurement, Assessment, Design, and Analysis (RMADA) IDIQ with the primary task order targeting improving the disability process).
- Funding applied for: To NIH, “Classification Logic Infrastructure and High Usability Web Tools for Integrating Science and Practice.”

Conclusions

The results to date indicate that ICF does offer the hypothesized utilities for a flexible balance between standardizing and evolving rehabilitation assessment and tracking progress with TBI patients and more broadly within the Polytrauma care system.

The results also show that TBI and Polytrauma clinical care providers and researchers work within a highly complex environment with multiple levels of administration and regulatory requirements, and contend with redundancies and other inefficiencies and gaps in their workflows. By addressing some of these inefficiencies, the mdlogix Clinical Research Management System-Health Science Process Framework (“CRMS-HSPF”) has engaged TBI clinical researchers, and provides them with value.

In spite of delays, what has been learned supports the vision and hypothesis of CRMS-HSPF serving as an infrastructure platform for implementation of the WHO ICF to provide diverse users with increased standardization in classification coding for TBI soldiers and veterans. The work planned for the second year of the project is expected to move this forward to a usable web product, integrated with clinical research processes and applicable to clinical care.

In addition, the richness of organizational relational data that was and can be collected and analyzed offers considerable potential as a scientific basis for methods and tools to be applied to organizational improvement and optimization, i.e., Relational Network Optimization (RNO). However, significantly more study and field testing, outside the scope of the current project, is needed to move RNO into a scientific product.

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Appendices

- ICF TBI Comprehensive Care Set
- “Case Report: Using Relational Network Optimization for Improving Health Care Coordination and Delivery in a Polytrauma Continuum of Care”

Comprehensive ICF Core Set for Traumatic Brain Injury

ICF Code ICF Category Title

Body Functions

- b110 Consciousness functions
- b114 Orientation functions
- b126 Temperament and personality functions
- b130 Energy and drive functions
- b134 Sleep functions
- b140 Attention functions
- b144 Memory functions
- b147 Psychomotor functions
- b152 Emotional functions
- b156 Perceptual functions
- b160 Thought functions
- b164 Higher-level cognitive functions
- b167 Mental functions of language
- b210 Seeing functions
- b215 Functions of structures adjoining the eye
- b235 Vestibular functions
- b240 Sensations associated with hearing and vestibular function
- b255 Smell function
- b260 Proprioceptive function
- b280 Sensation of pain
- b310 Voice functions
- b320 Articulation functions
- b330 Fluency and rhythm of speech functions
- b420 Blood pressure functions
- b455 Exercise tolerance functions
- b510 Ingestion functions
- b525 Defecation functions
- b555 Endocrine gland functions
- b620 Urination functions
- b640 Sexual functions
- b710 Mobility of joint functions
- b730 Muscle power functions
- b735 Muscle tone functions
- b755 Involuntary movement reaction functions
- b760 Control of voluntary movement functions
- b765 Involuntary movement functions
- b770 Gait pattern functions

Body Structures

- s110 Structure of brain
- s710 Structure of head and neck region

Activities & Participation

- d110 Watching
- d115 Listening
- d155 Acquiring skills
- d160 Focusing attention
- d163 Thinking
- d166 Reading
- d170 Writing
- d175 Solving problems
- d177 Making decisions
- d210 Undertaking a single task
- d220 Undertaking multiple tasks
- d230 Carrying out daily routine
- d240 Handling stress and other psychological demands
- d310 Communicating with – receiving – spoken messages
- d315 Communicating with – receiving – nonverbal messages
- d330 Speaking
- d335 Producing nonverbal messages
- d345 Writing messages
- d350 Conversation
- d360 Using communication devices and techniques
- d410 Changing basic body position
- d415 Maintaining a body position
- d420 Transferring oneself
- d430 Lifting and carrying objects
- d440 Fine hand use
- d445 Hand and arm use
- d450 Walking
- d455 Moving around
- d465 Moving around using equipment
- d470 Using transportation
- d475 Driving
- d510 Washing oneself
- d520 Caring for body parts
- d530 Toileting
- d540 Dressing
- d550 Eating
- d560 Drinking
- d570 Looking after one's health
- d620 Acquisition of goods and services
- d630 Preparing meals
- d640 Doing housework
- d660 Assisting others
- d710 Basic interpersonal interactions
- d720 Complex interpersonal interactions
- d730 Relating with strangers
- d740 Formal relationships

- d750 Informal social relationships
- d760 Family relationships
- d770 Intimate relationships
- d825 Vocational training
- d830 Higher education
- d840 Apprenticeship (work preparation)
- d845 Acquiring, keeping and terminating a job
- d850 Remunerative employment
- d855 Non-remunerative employment
- d860 Basic economic transactions
- d865 Complex economic transactions
- d870 Economic self-sufficiency
- d910 Community life
- d920 Recreation and leisure
- d930 Religion and spirituality

Environmental Factors

- e1100 Food
- e1101 Drugs
- e1108 Non-medicinal drugs and alcohol
- e115 Products and technology for personal use in daily living
- e120 Products and technology for personal indoor and outdoor mobility and transportation
- e125 Products and technology for communication
- e135 Products and technology for employment
- e150 Design, construction and building products and technology of buildings for public use
- e155 Design, construction and building products and technology of buildings for private use
- e160 Products and technology of land development
- e165 Assets
- e210 Physical geography
- e250 Sound
- e310 Immediate family
- e315 Extended family
- e320 Friends
- e325 Acquaintances, peers, colleagues, neighbours and community members
- e330 People in positions of authority
- e340 Personal care providers and personal assistants
- e355 Health professionals
- e360 Other professionals
- e410 Individual attitudes of immediate family members
- e415 Individual attitudes of extended family members
- e420 Individual attitudes of friends
- e425 Individual attitudes of acquaintances, peers, colleagues, neighbours and community members
- e440 Individual attitudes of personal care providers and personal assistants
- e450 Individual attitudes of health professionals
- e455 Individual attitudes of other professionals
- e460 Societal attitudes
- e515 Architecture and construction services, systems and policies

e525 Housing services, systems and policies
e535 Communication services, systems and policies
e540 Transportation services, systems and policies
e550 Legal services, systems and policies
e570 Social security services, systems and policies
e575 General social support services, systems and policies
e580 Health services, systems and policies
e585 Education and training services, systems and policies
e590 Labour and employment services, systems and policies

Case Report: Using Relational Network Optimization for Improving Health Care Coordination and Delivery in a Polytrauma Continuum of Care

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Background

Effective communication is a foundational element of organizational functioning. The increasingly electronically networked world has brought about dramatic changes in how we can communicate and hence work together towards shared goals [1, 2]. Hospitals and other health care organizations are perhaps the most complex of human creations [3], and embody some of the greatest challenges from these complexities multiplied by the growing number of specialized health care work roles and responsibilities [4-9].

Furthermore, care has shifted conceptually from the singular “Provider:Patient” model into a greater recognition of the importance of “the health care continuum”. Increasingly, diverse and distributed teams are responsible for the care and management of patients with a wide range of risk factors, injuries, disorders, and impairments. A major constraining barrier to needed innovations is a lack of systematic and practical understanding of how people in different roles are interacting to carry out their tasks, and how these organizational structures, social networks of people working together, can be supported and modified to continually learn and become more productive and efficient [10]. It is by means of these social structures that the effective communication needed for optimal performance can occur.

To address these needs and challenges and elevate this constraint, Medical Decision Logic, Inc. (“mdlogix”) from its founding in 1997 established a solution package for innovation as a process to address the need for systemic and quantifiable analysis and interventions to improve health care social network structures – ‘Relational Network Optimization™’ (RNO™). Built on decades of experience delivering innovative value to large and complex enterprise environments with applied health sciences informatics, including role and task analysis and user-centered automation-based restructuring of complex clinical research workflows at a globally leading academic medical center (with consequent productivity gains approaching billions of dollars), RNO offers a standardized approach with a supporting software toolset for using Social Network Analysis (SNA) methodologies. The term SNA as typically used is in several ways equivalent to the term Network Science, recently defined as “*the study of the collection, management, analysis, interpretation, and presentation of relational data*” [11]. RNO is a form of ‘network intervention’, “*the process of using social network data to accelerate behavior change or improve organizational performance*” [12].

In these experiences, and more generally [13-33], effective diffusion of innovation in health care organizations appears to depend upon internal individual leaders and their relationships. RNO provides a means of obtaining knowledge of and engagement with influential key players and opinion leaders, assisting and empowering them to build on institutional accomplishments and successes. More comprehensive knowledge of organizational structure offers a means of guiding network interventions for efficiency and cost-effectiveness. RNO offers a robust process and tools

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for categorically identifying key players, quantifying the relative positions and influence strengths of individuals within an organization, and observing work relationships within and between individuals, roles, teams, and organizations. Consistent with and extending the large body and long history of industrial and organizational research, consulting services, and the like, RNO is a people-centered technologically-enabled means of scientifically guiding and monitoring cycles of improvement interventions and implementations. As a standardized approach, RNO offers a means of more fully understanding an organization's established best practices in order to make these more available to other organizations. In addition, it integrates science and practice in a manner designed to accelerate cycles of data, information, and scientific knowledge interacting with decisions, actions, and outcomes.

RNO is being interactively applied to study and develop approaches to systematically improve the care of soldiers and veterans, supported by a Department of Defense (DoD) Investigator-Initiated Award to Dr. Tien at mdlogix, *"A Health Science Process Framework for Comprehensive Clinical Functional Assessment"*. Description of the baseline application of RNO follows.

Polytrauma Continuum of Care

Located in Richmond, Virginia, the Polytrauma Continuum of Care (CoC) at the Hunter Holmes McGuire Veterans Administration Medical Center was built to support the Rehabilitation of the most severely combat injured Wounded Warriors suffering from Traumatic Brain Injury (TBI) and blast-associated Polytraumatic injury. The primary goal, successful community re-entry, requires a step-wise program-based approach from intensive inpatient rehabilitation medicine, through residential programs, and eventual transition to life-long outpatient care of highly variable intensity.

The Polytrauma CoC is comprised of four major units: Inpatient Polytrauma Rehabilitation Center (PRC); Polytrauma Residential Program (PTRP); vocationally-focused residential Service member Transitional Advanced Rehabilitation Program (STAR); and Outpatient Polytrauma Network Site (PNS), plus Inpatient Nursing (2BN) and Outpatient Nursing (514N). Additionally, the CoC is supported by Centers of Excellence in Assistive Technology, Amputee Rehabilitation, and Epilepsy.

The Polytrauma CoC exists within a large and comprehensive tertiary care hospital. As is typical in these robust clinical care settings, more than half of the personnel assigned to the Polytrauma CoC report to supervisors outside the CoC. For example, many therapists and nurses have clinical and organizational responsibilities beyond just a single unit, and sometimes these responsibilities are elsewhere in the Medical Center, beyond the Polytrauma Rehabilitation System itself. The Physical Medicine and Rehabilitation Service serves as the business owner of the CoC, but also has dedicated responsibility to provide care in other areas, including acute care, longterm care, spinal cord injuries, amputations, and other clinical situations that can benefit from rehabilitation activities.

One of the five Polytrauma Rehabilitation Centers and a partner site of the Defense and Veterans Brain Injury Center, the Richmond Polytrauma CoC provides outstanding care and is a leading model for the national VA Polytrauma System of Care. However, as each of the cognate Polytrauma Rehabilitation Centers and the 23 Polytrauma Network Sites, 87 Polytrauma Support Clinic Teams, and 39 Polytrauma Points of Contact continually seek to further advance the quality and efficiency of care, the organizational complexity inherent within this heavily matrixed

environment presents conceptual and technical challenges. Providing a methodology for understanding in greater scientific depth the organizational structures and communication behaviors underlying the specific workflows within the Richmond Polytrauma CoC in order to more fully model as a comparison and guide to other centers, as well as to increase internal awareness and capacity, RNO can overcome these challenges.

mdlogix Relational Network Optimization (RNO) Approach

RNO is a new approach to an old problem that applies historical knowledge, expertise in enterprise innovation, network science, business science, and web technology to identify and overcome constraints and optimize human capital throughput. In a singular process, mdlogix provides an end-to-end solution for perceiving and understanding organizational strengths as well as constraints and opportunities in order to promote improvements in operational efficiency and effectiveness, and hence provide the ‘bottom line’ benefits of improving health care outcomes. RNO is intended to make the organizational “social hieroglyph” [34] more legible and standardized in a constructive and productive manner.

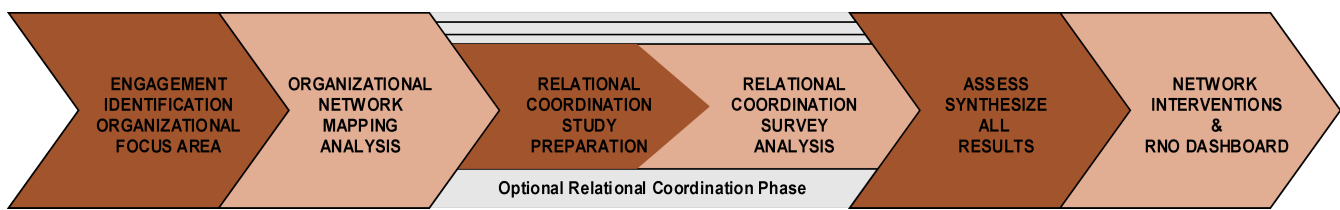


Figure 1. Relational Network Optimization (RNO) workflow

Depicted above, RNO is structured with three phases named Organizational Network Mapping (ONM), Relational Coordination Study (RC), and Rapid Cycle Intervention (RCI). Each phase has two closely linked components, shown by the darker and lighter shading. ONM and RC are composed of engagement and preparation followed by data collection and analysis. RCI is composed of further analysis and synthesis of prior results followed by specified network intervention(s).

Metaphorically, RNO combines a mirror and a microscope, along with a set of terms for conceptualizing and thinking about the observations, enabling people working in different worlds to see themselves and others and then communicate and develop common understandings. It is also a methodology for positive engagement with people to empower them to educate themselves with sometimes sensitive information. Because it is focused on observing individuals, roles, teams, and organizations, RNO results can potentially be used to incrementally guide its own application.

The RNO approach couples analysis and intervention intrinsically in each phase. It is designed to build on results and learning in each phase and component to evolve and repeat as an ongoing and increasingly specific process. It is intended to enable and motivate a progressive understanding and participatory optimization of the unique human networks residing locally within a particular organization, and by more fully identifying and describing best practice models and lowering barriers to gaining this knowledge, catalyze larger systems changes.

ONM: Organizational Network Mapping is the network science framework and operational core of RNO. Its purpose is to increase the capacity of an organization's members to perceive the structure of the important work relationships of the individuals, teams, and other workgroups that make up the organization.

In the ONM engagement and preparation component, key areas of an organization's operations, prioritized work relationships, goals, and other contextual information are identified. This is accomplished through iterative process built through in-person engagement, exploration, and in-depth discussion with a full range of organizational members. This component starts with and strengthens working relationships with organizational leaders; it also brings in representatives of prioritized staff roles. The output is the determination and semantically refined description of one or more work relationships, such as 'care coordination', and a list of the names of all staff who are part of those relationships. As an intervention it guides leadership in identifying and prioritizing the various key, shared tasks within the workgroup.

In the ONM data collection and analysis component, data is collected and analyzed using mdlogix's SocioWorks toolkit (e.g., SocioScope, Visualyzer). Data is collected using webpads with a graphical display that makes it easy for participants to visually draw relationship lines between the listed people. If preferred by participants, the same format can be used to collect data on paper, which is then readily entered into the software. The results include a visual display of relational networks based upon key workgroup tasks, quantification of network properties such as density and cohesion, algorithmic identification of key organizational players and subgroups, and quantification of individual network member attributes including degree of connectivity, network position, and bridging. These results immediately inform potential network interventions such as to bridge identified gaps, e.g., putting in place a new meeting structure with key individuals.

RC: Relational Coordination, based on emerging developments in management science, provides a quantitative model with seven role-to-role constructs: Shared Knowledge, Shared Goals, Mutual Respect, Timely Communication, Accurate Communication, Problem-Solving Communication, and Frequent Communication, and is a methodology for studying and improving the coordination of work between organizational roles [35].

It is a valuable part of RNO, complementing ONM with a specific relational model supported by a growing body of work, scientific evidence and knowledge, and experience. In health care Relational Coordination has proven to improve quality of care and associated outcomes in diverse settings [36-41].

Because of the needed additional effort and calendar time, the RC phase of RNO can be deferred until organizations are ready for subsequent incorporation and application at different organizational levels [42], such as with front-line teams, administrative groups, or spanning organizational sectors or divisions.

In the RC engagement and preparation component, ONM results contribute to the design of the specific RC Survey, instantiating the RC model template based on organizational functional roles, prioritized tasks, and representative members.

In the RC data collection and analysis component, participants rate relationships with a 1 to 5 range for each of the seven RC constructs. RC scores are aggregated and analyzed using Socioworks for organization groupings and levels. Reference norms are in below table.

	Within Workgroups	Between Workgroups	Between Organizations
Strong	< 4.5	< 4.0	< 3.5
Moderate	4.0 – 4.5	3.5 – 4.0	3.0 – 3.5
Weak	> 4.0	> 3.5	> 3.0

RCI: The Rapid Cycle Intervention phase, based on ONM and available RC results, is intended to define and support network interventions that improve and optimize organizational structure and function, establishing an organizational process for ongoing improvements.

In the RCI engagement and preparation component, all available prior results and information are combined in tabular and graphical displays, and detailed discussions are provided and led by mdlogix with a representative range of organizational participants. This is an in-depth conceptual assessment and knowledge synthesis that seeks comprehensive qualitative and quantitative understanding of structural gaps and low scores in assessment results, “triangulating” with ONM, RC, and qualitative and narrative observations. Results of this component include a summary of potential and recommended network interventions.

In the RCI intervention component, mdlogix staff report and review all preparatory results with organizational leadership, helping them to think through and optimize best practices. Potential network interventions are discussed, jointly prioritized, planned, and initiated. The RNO process supports these RCI activities for breakthrough changes in accelerated timeframes, including web service RNO Dashboards for real-time monitoring of cycles of interventions with dynamic data updates and longitudinal graphics.

RNO, as a form of intentional organizational change for health care systems, is designed to encourage both strong support from leadership and buy-in from all stakeholders, including patients and family caregivers. Active engagement with personnel at all organizational levels and RNO phases garners higher levels of interest and participation than would be the case with simply providing surveys to collect data. The accordant learning, at conceptual, specific organizational, and tool use levels, is a major aspect of intervention.

RNO at the Polytrauma CoC

The Polytrauma CoC has distinct program structures built around team-based care delivery. The delivery of quality care along a continuum requires multiple interdependent relationships within and between units, carried out by diverse individuals working in different professional roles (e.g., RN, MD, Social Worker, Therapist). Polytrauma CoC is a state-of-the-art care system with a strong and shared mission and impressive quality outcomes, based upon a high level of team integration and care coordination. Nevertheless, Polytrauma CoC leadership continue to seek further improvements in care communications and with the transitions of Wounded Warriors between program units along the care continuum.

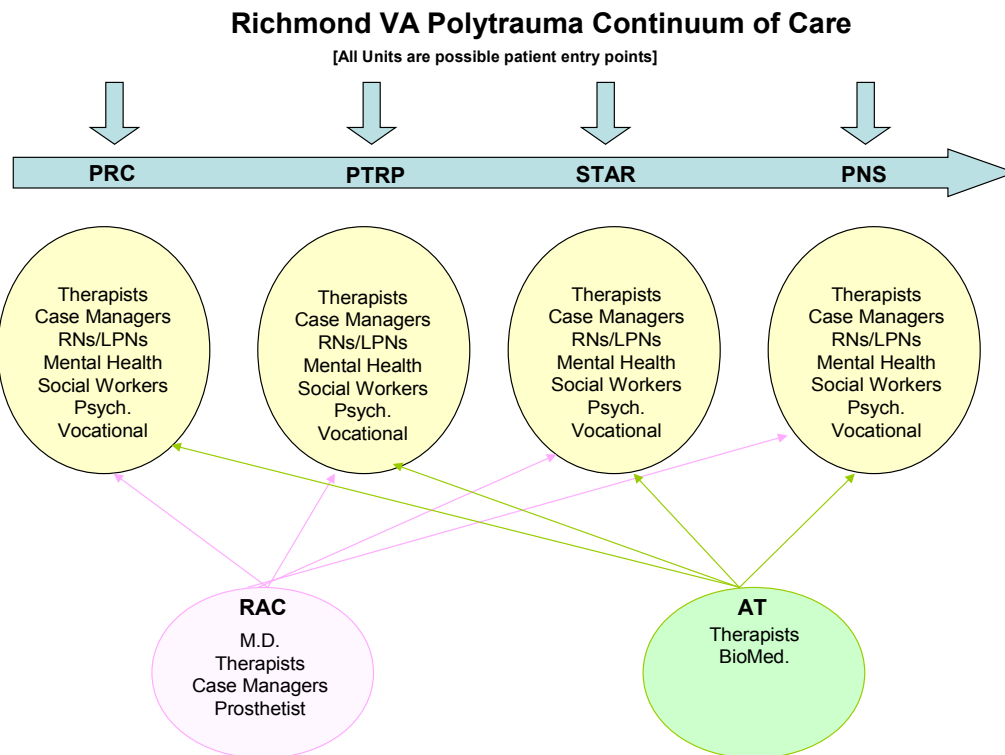


Figure 2. Polytrauma Continuum of Care Unit Structure

As introduced earlier, the mdlogix RNO solution incorporates an interacting sequence of three phases: Organizational Network Mapping (ONM), Relational Coordination (RC), and Rapid Cycle Intervention (RCI). To initiate RNO, the Polytrauma Continuum of Care's unit structure, workflow, and data flows were provided to the mdlogix team. From that, mdlogix created a high-level graphical view of the system, shown above in Figure 2.

Phase 1: Organizational Network Mapping (ONM Phase)

ONM Engagement and Preparation: The mdlogix team held in-person meetings with the Medical Directors and key staff in each of the Polytrauma CoC units to discuss the RNO process and to gain further insight into the activities and staff roles involved in the delivery of their steps of the Continuum of Care. These meetings were scheduled over about eight weeks, and including conference calls, totaled about 40 hours. In this process, five workflow relationship categories that span the CoC were identified as the priority targets for ONM: Program Development, Therapeutic Planning/Diagnosis, Care Coordination, Caregiver Support, and 'Other'. The names of the 220 Polytrauma CoC personnel members were obtained and their roles listed.

To carry out ONM, mdlogix created and provided both tablet-based and paper-based organizational mapping templates to allow participants to rapidly and accurately record their person-to-person relationships within and between the units that comprise the Polytrauma CoC. Polytrauma senior leadership communicated with their teams on the importance of the project and encouraged direct involvement.

ONM Data Collection and Analysis: During the ONM data gathering stage, mdlogix RNO team members were frequently on-site at Richmond to support Polytrauma CoC staff members in populating the organizational network maps. This included being invited to take a time-slot in

scheduled staff meetings in each of the system's units to provide a RNO overview presentation, to have one-to-one sessions with various participants, to meet with nursing staff at shift-handover sessions, etc.; generally, helping with the timely completion of the individuals' network maps so as to minimize disruption to their day-to-day workload. Polytrauma CoC staff consistently reported a high degree of satisfaction with the process, and demonstrated a high level of interest in the exercise.

In conjunction with the completion of the mapping exercise, mdlogix created a workbook for capturing information about perceived 'Influencers' in the organization, in relation to the targeted relational workflows. These 'Influencers' were defined as individuals perceived as having a level of influence greater than would typically be expected of the position/role that they currently hold. This workbook was issued for completion by the medical directors in charge of each of the units, and by 2-3 key clinical and administrative members of their choice within each of the units.

On average, even without support from the mdlogix team, completion of an individual's maps took under 20 minutes. Of note, interest in what the mdlogix RNO team was doing on-site was even expressed directly to team members by patients in the Polytrauma CoC (although they were not involved in data collection). The Polytrauma's staff 'educator' also provided valuable support to the RNO team in helping participants complete their individual maps. The on-site presence and availability of the mdlogix RNO team, and the face-to-face interactions that team had with many members of the Polytrauma system staff, greatly encouraged participation and created trusted relationships that benefitted the overall pursuit of the goals of the project. As a result, the mdlogix RNO team members gained deeper insight into how the Polytrauma system functions, both formally and informally. Additionally, the engagement of teams and iterative use of their inputs creates "psychological ownership" of the process and the results [43].

Once the ONM data was collected from individual staff respondents (N = 120), SocioWorks software was used to produce electronic 'organizational network maps' that combined relationship data from each individual map, plus influence data. These network maps, with as many as 220 relationship-linked network nodes (Polytrauma CoC personnel) visually represent team structure, role relationships, and influence within and across units based upon the identified key workflow relational tasks. The number of related nodes is higher than the number of respondents since each respondent provided data on all of the relationships they are aware of, not just their individual relationships, and not every staff member was a respondent.

Resultant organizational network maps are shown below for Care Coordination, Therapeutic Planning/Diagnostics; and Caregiver Support relationships within and between six organizational groups from upper left and counterclockwise: inpatient nursing (2BN), PRC, PTRP, STAR, PNS, and outpatient (514N) nursing.

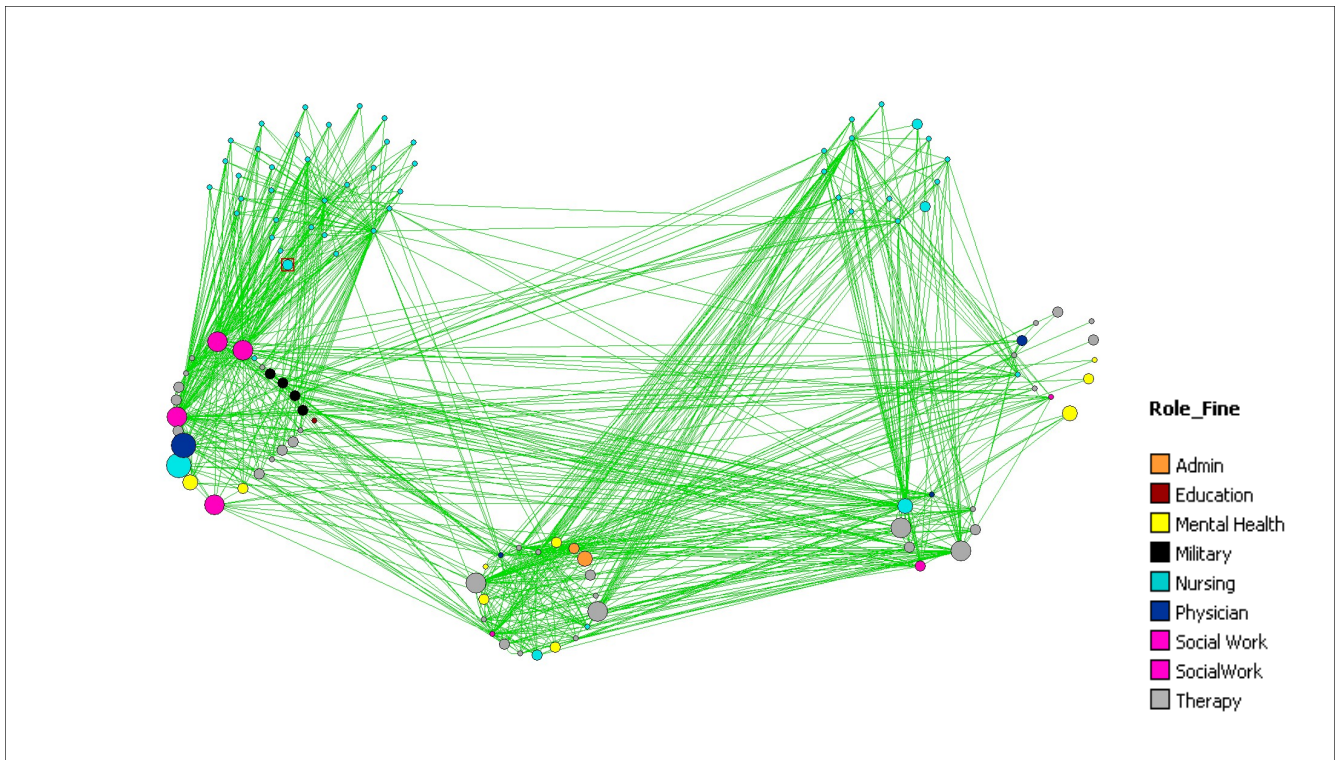


Figure 3. Care Coordination Relationships

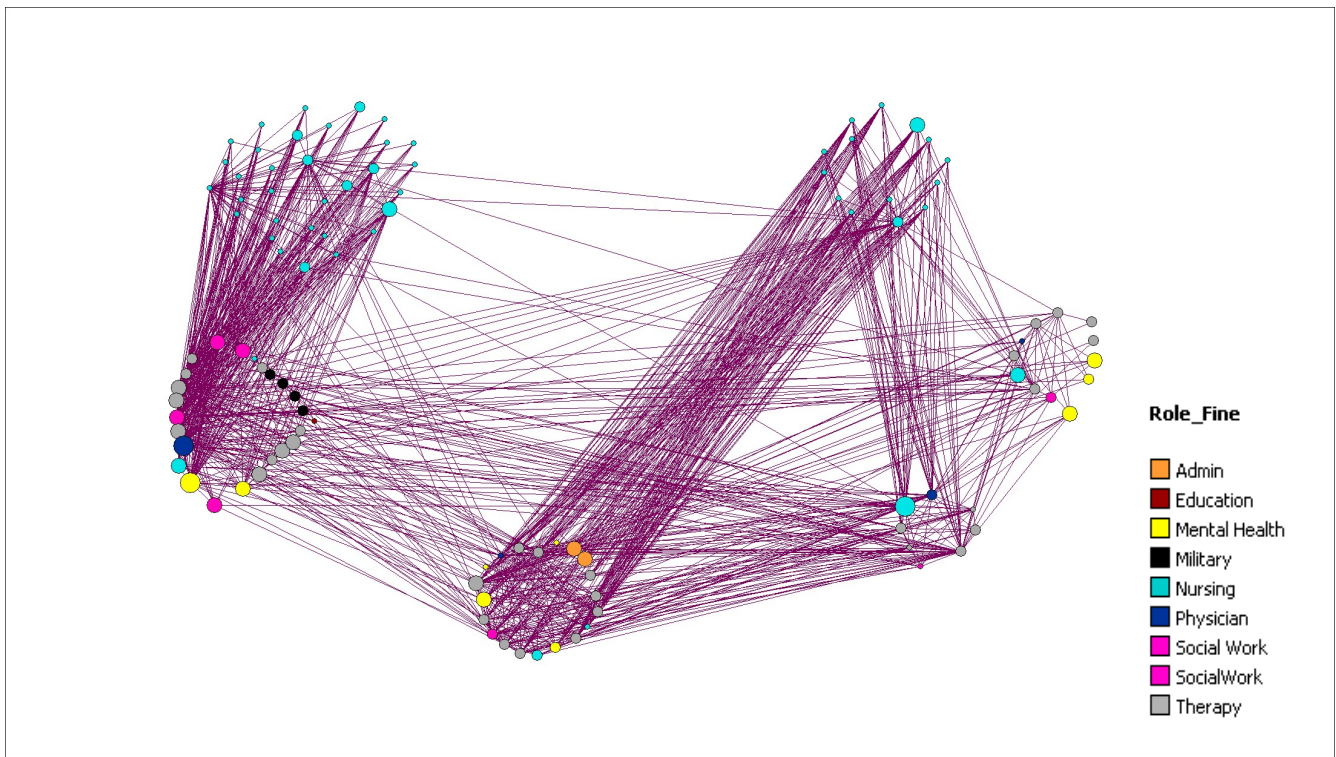


Figure 4. Therapeutic Planning and Diagnostics Relationships

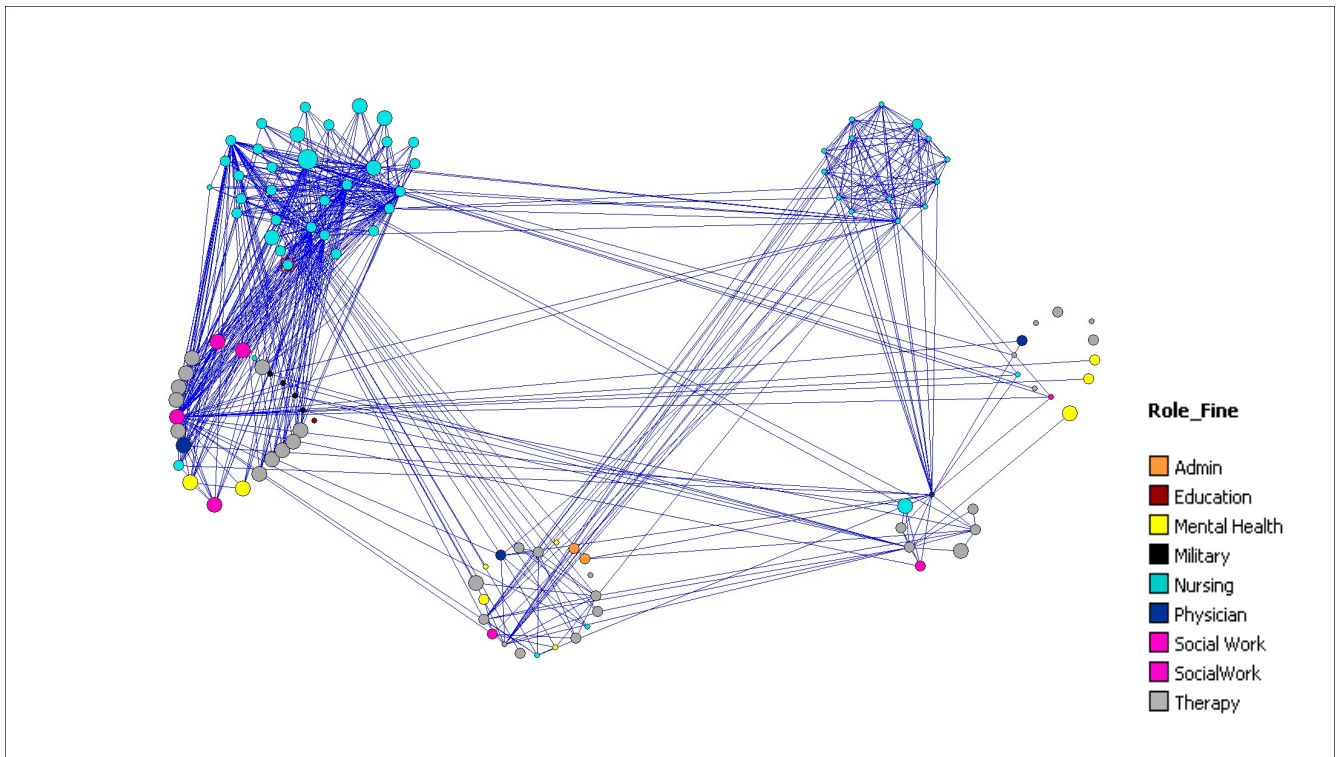


Figure 5. Caregiver Support Relationships

In Figures 3, 4, and 5, the level of Influence on the specified relationship is shown by the size of each node (person), and the roles are shown by color as labeled (“Role_Fine”). Because the Polytrauma CoC cares for active duty personnel as well as veterans, Military care personnel are present (coded with black).

These visualizations contain and convey substantial information about different aspects and levels of professional roles and relationships within the Polytrauma CoC. Overall, there is clearly a high degree of professional relationships and hence interactions between Polytrauma CoC units, as well as within units.

In Figure 3, showing Care Coordination relationships, all the units are connected, with dense connectivity between inpatient nursing (2BN) and the inpatient unit (PRC), with the highest density between nurses and a subset of the PRC therapists. The residential unit (PTRP), is extensively connected with the inpatient, transitional (STAR), and outpatient (PNS) units, and also with the outpatient nurses. The two nursing groups are connected by only two inpatient nurses with one outpatient nurse. Interestingly, almost all of the nodes (individuals) with the highest Influence (size of the circles), are four Social Workers and four Therapists, although the Influence of the single Physician and single Nurse is larger.

In Figure 4, showing Therapeutic Planning and Diagnostics relationships, there is a similar pattern of high connectivity between inpatient nursing and the inpatient unit, and with PTRP to other units. Some differences are that the inpatient nurses have higher Influence, and the inpatient connectivity appears even higher than for Care Coordination. Likewise, there is a very high level of connectivity between PTRP and outpatient nursing. As with Care Coordination there is less connectivity between inpatient nursing and all the non-inpatient units, and only two

inpatient nurses are linked to a single outpatient nurse. The PNS unit had the most connectivity, as compared to Care Coordination and Caregiver Support, and Mental Health staff had higher Influence.

In Figure 5, showing Caregiver Support relationships, overall connectivity is much lower than with Care Coordination and Therapeutic Planning and Diagnostics. Interestingly, the connectivity is still high between inpatient nursing and the inpatient unit, and with the inpatient nurses as a whole having much higher Influence than with the other relationships shows. The display shows that almost all of the links between inpatient nursing and PTRP are with a single nurse linked to nearly of the PTRP unit members. Also, the outpatient nursing unit is densely internally connected, while the majority of PNS members were not linked to each other, and sparsely to other units. Almost all of the Therapists had relatively high Influence.

All of these relationships are quantified using an array of SNA measures, including density and cohesion for groups (any groups can be defined and then quantified, e.g., by role, by unit, by gender, by age), the occurrence of subgroups, and for individuals, node degree, centrality, key player, and bridging scores.

These maps highlighted patterns of relationships that exist in the organization in support of care activities. The process of ONM immediately helped create further buy-in from team members and resulted in these team members' growing appreciation of the nature of network science and RNO as applied to the Polytrauma CoC workplace and associated work activities.

The ONM Phase provided powerful information on its own, showing the strength of the direct care relationships, as well as a potential advantage to be gained from further understanding of Caregiver Support relationships. It also assisted in preparation for the RC Phase by developing contextual knowledge of Polytrauma CoC work relational networks and their functional teams, groups, and roles. ONM results were used to guide representative sampling for the RC survey, in order to lower overall response burden.

Phase 2: Relational Coordination Study (RC Phase)

RC Engagement and Preparation: To start the RC phase, the mdlogix team conducted a series of in-person meetings and conference calls, amounting to a total of approximately 30 hours. These discussions partially overlapped in calendar time with the ONM activities.

The discussions progressed from 1) familiarization about the RC concept and its utility and impacts, especially in health care and care coordination, to 2) the goals of each unit and the entire Richmond Polytrauma CoC, including the desire to improve patient experience, improve patient outcomes, improve respect among colleagues, and make care coordination more efficient, to 3) the specifics of conducting the survey, particularly which task/work process should be the focus, which roles would be relevant to interview regarding that task/work process, whether and how to sample the roles rather than interview everyone, how to deploy the survey, and testing/editing the survey.

From these discussions, the decision was made to focus the RC Study on the functional task of 'Patient Transfers Between Units'. In the transfer process, the distinction was made between 'Referring' and 'Accepting', directionally defining the between-role relationship and

communication RC dimensions. In the patient transfer process, RC was applied within Units as well as between Units. The eleven defined Roles were Medical Directors , Mental Health Personnel, Nurse Case Managers, Social Workers, and Therapists in both directions 5 Roles x 2 directions), and Nurse/Nurse Supervisors without directionality.

RC Data Collection and Analysis: Across the four main Units (PRC, PTRP, STAR, and PNS), 44 people were invited to enter data on-line, and 32 participated, with representation across the four Units (PRC = 13, PTRP = 7, STAR = 5, PNS = 7), and, overlapping the defined Roles, professional roles (Physician = 4, Nurse = 3, Therapist = 14, Patient Manager = 6, Mental Health Personnel = 5).

Scores were automatically calculated at various levels of aggregation, including identified Strengths (the highest rated dimensions) and Opportunities (the lowest rated dimensions) between and within Units by defined Roles, Strong and Weak RC Ties (pairs of relationships in which there is disagreement in the data between the two directions), RC scores for the seven dimensions between and within Units, overall RC score by defined Role within and between Units, then detailed breakdowns for each of the seven RC dimensions for each defined Role within and between Units.

Overall RC results showed a majority of scores in the Strong range. For example, Figure 6 shows a grid of total RC scores by the Units (rows) making the ratings, by Roles, Accepting and Referring (columns). Of the 55 total scores, only 9 were Weak, 18 were Moderate, and 28 were Strong. Furthermore, of the Weak score, the lowest was 3.2, and all were close to Moderate.

Findings: Relational Coordination by Unit, by Role

		Ratings Of									
Ratings By	Unit	Accepting					Referring				
		MD	MH	NCM	SW	Ther	MD	MH	NCM	SW	Nrsg
	PRC	4.2	3.8	3.9	4.2	3.8	4.2	4.0	4.2	4.3	3.9
	PTRP	3.6	3.3	3.2	3.4	3.7	4.0	3.6	4.0	3.6	3.8
	STAR	4.2	4.0	4.2	4.1	4.2	4.2	3.9	4.0	4.1	4.1
	PNS	3.6	3.3	3.7	3.7	3.4	3.4	3.3	3.5	3.5	3.3
	Nrsg	4.1	3.8	4.3	4.2	4.1	4.1	4.0	4.1	4.1	4.2

Weak

Moderate 3.5 - 4.0

Strong

Figure 6. Total RC Scores by Unit by Role

For the individual RC dimensions scores (not shown here) by the eleven Roles, there were no Strong scores for Timely Communication for any Role between Units, with four Weak scores and six Moderate scores. There were no Strong scores for Accurate Communication between Units, and there were four Weak scores for Accurate Communication within Units.

Other detailed results showed that between Units Frequent Communication was Strong, while Timely Communication was Weak. Within Units Frequent Communication was also Strong, while Problem-Solving Communication was Weak. While Social Workers-Accepting were rated Strong within Units, Nurse Case Managers-Accepting and Therapists-Accepting were rated Weak.

Two sets of ties (relational coordination dimensions) were observed with discordant ratings, i.e., Strong ties reported from one Role paired with Weak ties reported by the other Role. These were Mental Health Personnel with Social Workers, and Therapists with Social Workers, with the Social Workers in both sets reporting that the ties were Weak while the other Roles reported that the ties were Strong.

Between Units, the two lowest overall RC scores were Timely Communication (Mean 3.48, Min 3.11, Max 3.66) and Shared Knowledge (Mean 3.48, Min 3.21, Max 3.77), both in the Weak range. Within Units, the single Weak RC score was Problem-Solving Communication (Mean 3.97, Min 3.00, Max 5.00).

In terms of directionality between Roles, which was only between Units, there were Weak scores for three Roles, Medical Directors-Accepting, Nurse Case Managers-Accepting, and Therapists-Accepting.

Our next step in RC Analysis will be to calculate results about how each of the four Units see the other Roles on average, such as how STAR sees accepting nurse case managers on the seven communications and shared understandings questions of the RC construct. This will allow us to quantify how Units perceive Roles. We will also be able to observe how Roles within Units see other Roles.

Overall, RC results show that Frequent Communication is Strong both between and within Units, while Timely Communication and Shared Knowledge between Units are Weak (albeit just at the edge of Moderate), and Problem-Solving Communication within Units is Weak (again just at the edge of Moderate). No extreme Weak scores were present. Any scores that are not Strong represent an opportunity for improvement.

Phase 3: Rapid Cycle Intervention (RCI Phase)

The RCI Phase of RNO has been initiated at the Polytrauma CoC. The presentation below is intended to provide an early illustration of the analysis and potential interventions.

RCI Analysis: Immediately when available, ONM results were discussed in multiple sessions over several weeks with leadership and staff, and analyzed in combination with their knowledge about the organizational structure and operations of Polytrauma CoC. The results of the RC Phase, with data collection carried out following the end of the ONM Phase, are currently being brought into the discussion. The results to date are summarized below.

Between Units

In total, ONM shows a high degree of connectedness between Units, and RC shows Frequent Communication is Strong. This is consistent with the high level of motivation and care activity established in the Polytrauma CoC culture, and the strong focus on care coordination.

In detail, some potential areas for improvement are evident. There is no set of people across all Units that report regular interactions together for any given relational network, although the Care Coordination relational network comes close with an identified group of seven interlinked individuals, only missing representation of one Unit (PTRP). Caregiver Support is the least connected relational network between Units, with the exception of very high connectedness between PRC and 2BN. Across all of the ONM relationships, connectedness is low between the two nursing staff groups (inpatient and outpatient). RC results showed Timely Communication and Shared Knowledge to be relatively low between Units.

Nevertheless, certain individuals have major connectedness between Units, and it is not always the same individual. For example, one person is highly centralized between PTRP and PNS for Care Coordination and Therapeutic Planning/Diagnosis, while a different person has this structural position between PTRP and PNS for Program Development. A third person held this position between PTRP and PRC for Care Coordination. Nine other individuals were identified who were highly central between other pairs of units and relationships.

Within Units

Connectedness was high within most Units for most relationships, but appeared low in PNS for Care Coordination, Therapeutic Planning/Diagnosis, and Caregiver Support, and also low in 2BN for Program Development. Consistent with this, aggregate RC scores within Units were generally high, with only Problem-Solving Communication being Weak. In general, within Unit connectedness should be high, just as RC scores should be highest within Units, as is the case here. Some next steps will be to disaggregate RC dimensional scores by individual Units, and to examine the analytic relationships between Problem-Solving Communication and the ONM measures.

Centralization was high within a number of Units and relationships. Of the total of 24 possible unit-relationship combinations (6 x 4, omitting the Other relational network), ten people were notably central to seven of these combinations. For example, one person was central within 514N for Care Coordination, Therapeutic Planning/Diagnosis, and Program Development, one person was central within 2BN for Program Development, and two people within PNS were central for Program Development and Therapeutic Planning/Diagnosis.

Within PNS, there was moderate centralization of Care Coordination, Program Development, and Caregiver Support; also, there were several members with low participation.

Influence

In RNO, the influence of individuals is scored by combined peer ratings. In small group theory, influential individuals are often the most connected. However, in the Richmond Polytrauma CoC, the association between influence and connectedness was not consistently present. This

interesting result suggests that this approach to measuring influence may be gaining information not otherwise captured. Or conversely, the defined and prioritized work relationships that data was collected on are somewhat distinct from ‘standard’ SNA measures of ‘friendship’ and ‘advice seeking’. In any case, identification (and engagement) of influential individuals has proven to be a key driver to institute positive change. An important feature of the RNO process is the ability to identify team members who are perceived as “Influencers” within the teams.

In the initial RCI discussions, Polytrauma CoC leadership obtained new knowledge from the identification of “Influencers”, particularly as the majority of these “Influencers” were not in roles of authority within the official organizational hierarchy. Rather, they work in a variety of different team-based roles, but were still identified by their peers as de facto leaders. What was also helpful was the knowledge gained from the visualization of the overall relational networks and levels of connectivity surrounding these key workflows.

RC

As applied herein to assess patient transfers, the RC Study was narrower in focus than the ONM, and more complex in terms of distinguishing directionality in relations. However, it does not provide results about individuals, only for Roles. Overall RC results showed many strengths, and also identified potential areas of improvement. Interestingly, RC results pointed to relative weaknesses in the relational coordination of receiving transferred patients (versus sending), and showed asymmetry between Social Workers versus Mental Health Personnel and versus Therapists. A number of other areas of relative weakness in RC were identified for detailed analytic discussion.

These discussions can be held with different sets of staff, such as separate units and groups of personnel by Role, and also should be held with combined groups, for example representing different RC ratings. Making use of ONM results, it may be helpful to discuss RC results with both individuals who are highly central and who are not well connected, in order to provide a more complete set of perspectives to guide potential interventions. Coupled with ONM, we will be able to suggest specific interpersonal relationships to target for support or leverage existing strengths.

RCI Network Interventions: At this stage, discussions and planning for potential network interventions are ongoing in the Polytrauma CoC. Network interventions can be conceptualized with four categories: 1) via identified key individuals; 2) via identified key subgroups; 3) via induction of network communication activities; and 4) via changing network structure [12]. Empowering network members in general with increased knowledge of network interventions is a related mode that can encompass all of these categories of intervention, but which perhaps can be defined as a type of network induction. Initial potential interventions are described within these categories.

1) via identified key individuals: Key individuals can be identified by a variety of network measures, such as centrality, bridging, and key player algorithms. They can also be identified by peer ratings, as is used in RNO. Interestingly, these approaches as applied in Polytrauma CoC appear to be complementary, although further analyses remain to be carried out. Once identified, this category of network intervention focuses resources on these key individuals to engage, educate, train, and otherwise empower them to diffuse innovation throughout the organization via their relationships.

2) via identified key subgroups: Likewise, key subgroups of people can be identified and then focused on to empower them to diffuse innovation, including making incremental changes in operational management. In the Polytrauma CoC, ONM results show that there is no clique or cabal of a small set of people who are connected across all the units. The closest to a clique of highly connected people is in the arena of Care Coordination as noted earlier. Since there is no natural group that links all of the Polytrauma CoC together, a potential intervention would be to draw upon existing central individuals to form a more formal group that meets occasionally to review past handoffs and/or reviews protocols or responsibilities. This would also be a type of structural intervention.

3) via induction of network communication activities: In general, strategic interaction between units, such as targeted inter-unit discussions, is expected to improve shared knowledge, and informed by ONM and RC results, this shared knowledge can and should include understanding of the various relational mappings, where there are weakness in the patient transfer process, and so forth, in order to increase their ability to communicate and coordinate with others.

One way to increase this understanding is for personnel to shadow other people from the same or different roles in another unit. Feasibly, this needs to be limited to 1-2 hours, perhaps up to a half a day at a time. Each person might shadow other roles once or twice per year, starting with strategic shadows first. Creating new relationships in this manner, along with new topics of discussion, if on target and aligned with the perceptions of personnel, and the organizational culture, can create significant activation and hence positive activity.

4) via changing network structure: A general possibility is to create new selected roles that are shared between units. These few roles are boundary spanners – one of their key responsibilities is to work across and between units. New connections can also be created. One way would be to move nurses, when they're willing and when possible, between the two nursing groups, which showed low connectedness with all of the work relationships. Over time, this could create new work relationships between nurses, and also, create new knowledge in their units about the work of the other unit.

However, all activities, especially creation of new structures and relationships, incur cost, both in effort and time, so determining optimal numerical degrees is an ongoing question that requires refined organizational specificity to answer accurately. Care must be taken to not overburden these roles, nor to rely on them as the exclusive intergroup tie for an activity. For example, the OT roles missing from PTRP could be shared with another unit.

On the other hand, defining and targeting specific levels of connectedness and influence could reduce excess redundancy, thus making communication more efficient between units by being more accurate and timely. This approach could help to equalize the relationship between connectedness and influence so that highly influential aren't disconnected and highly connected aren't uninfluential. These two do not require a one-to-one relationship, but it can be a lost opportunity when influential people are not connected and when connected people are not influential.

In cases where high influence is not matched by connectedness (i.e., when there is a relatively disconnected person who is perceived to have high influence), others who are central or high in

bridging could be asked to connect with those high influence people so they are drawn more into the collaborative work.

Other structural changes that over time could benefit overall performance would be to place and maintain at least one person and preferably two, possibly three, people in charge of each task process for inter-unit activities. For continuity and stability, it may be important to not rely on a single individual to be the central person for an important organizational bridging or connecting relationship roles (e.g., program, caregiver support), especially between units.

RCI Summary

The results sparked vigorous debate about should be done. It is apparent that not only Polytrauma CoC leadership but also personnel in general are highly motivated to maintain and further improve the current high quality of care. One aspect that the quantified information that RNO provides may help with is to increase efficiency. In this regard, it is apparent that RNO offers an innovative methodology for being critical, skeptical, and scientific about practicalities for organizational improvement, ensuring attendance to essential realities of functional social structure, codifying and automating what can be codified and automated, and leaving in place informal improvisations that require more complex and subtle judgements with unpredictable situations.

Actual interventions, in the reality of health care organizations composed of diverse individuals, face more complexity than ONM and RC can model and measure, and hence are intrinsically uncertain. However, the structural aspects of these applications of network theory are well founded on decades of scientific study as well as enterprise experience. The entire RNO process creates new shared knowledge, and the selection of network interventions should and will be a shared decision that creates new shared goals, and facilitates respect and more effective communication. This recursive aspect of RNO is expected to provide process stability at a 'social computational level' [44].

Conclusion

Experience to date at the Polytrauma Continuum of Care at the McGuire Hunter Holmes VA Hospital shows that RNO accurately measures meaningful constructs and advances scientific understanding of complex organizational structure. The results to date strongly suggest that RNO is useful to increase shareable knowledge about organizational strengths as well as opportunities for further internal improvements. The resultant structural knowledge and detailed parameters have potential to serve as a model and goals for programs at other locations.

The interest and motivation expressed by Polytrauma CoC staff participants, and also patients who happened to observe parts of the process, indicate that RNO naturally serves to raise awareness of the process as a platform for teaching team activities and work culture, and can facilitate more effective dialog between functional components of the full care team for a patient. It can be used for local organization change by creating the relational frame and making it easier to adapt and tune it, and can be used by hospital leadership to create a type of inclusive power by framing increased departmental accountability and service line effectiveness. It has potential for use by individuals to enable them to better question and change their own perceptions and thinking, showing how personal professional social network structures can be sources of

information, can be barriers, can activate teamwork care roles. RNO can be extended to involve patients and their family and friend caregiver networks, and could be used to ground focus decision-making on relationships with patients and family caregivers.

In considering the application of RNO as a standardized yet flexible approach to other settings, we note that leadership support and staff buy-in are critical for this or indeed any team-based intervention. Early and timely communication with, and involvement of, all team members facilitates this. Also, releasing results incrementally through a series of Rapid Cycle Improvements in a sensitive manner engenders further buy-in, and tangible gains encourage continued support and participation.

The comprehensive complexity of the Polytrauma CoC suggests that the mdlogix RNO approach is generalizable to other systems of healthcare organizational units that share a common mission. Due to resource constraints, RNO was only applied within Polytrauma CoC clinical care and management personnel; however, the larger context includes other important organizational divisions, sectors, and roles, including information technology and facilities engineering (who may have little relational activity with clinicians), and of course, patients and family caregivers, and the increasing numbers of them who use web and mobile technologies for communication and finding information. RNO thus can serve as a 21st century management and organizational learning tool that not only streamlines adoption by identifying and breaking choke points in organizational structure, workflow, and data processes, but also provides a concise model for attention that improves the value of human and machine processing.

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